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(54) Deposit reduction fuel injection valve

(57) A deposit reduction fuel injection valve (1) including a nozzle hole (3), formed on a tip portion (8) of a nozzle body so as to face a combustion chamber (2) of an internal combustion engine, for injecting directly fuel in said combustion chamber, and a temperature adjusting system (60) for adjusting a temperature of said tip portion of said nozzle body having said nozzle hole so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel.

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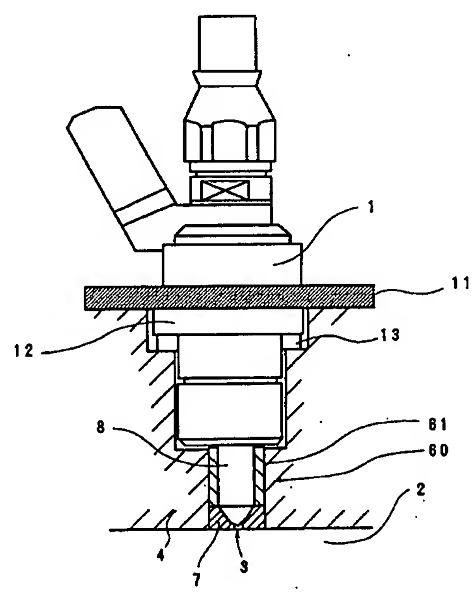

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a deposit reduction fuel injection valve comprising nozzle body which has a nozzle hole formed so as to face a combustion chamber of an internal combustion engine and which directly injects and supplies fuel to the combustion chamber, wherein temperature adjusting means for adjusting the temperature of a nozzle having the nozzle hole formed thereon adjusts the temperature of the tip portion of the nozzle body so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel, thereby suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole and hence resulting in reduced variations in a flow rate.

Description of the Prior Art

Accumulation of deposits on the internal surface of a nozzle hole O in a conventional fuel injection valve N shown in FIG. 12 results in a reduction in a flow rate. As will be described later, the accumulation of deposits is greatly dependent on the temperature of the tip end T of a nozzle. For this reason, the temperature of the tip end must be reduced when the fuel injection valve N is fitted to an engine E.

Attempts have already been made to reduce the temperature of the injection valve. However, these conventional attempts are principally directed toward

(1) preventing irregular injection due to the occurrence of cavitation in the nozzle;
(2) preventing a needle valve from seizing up or abrading when traveling inside the nozzle; and
(3) preventing a material of the nozzle from deteriorating, by suppressing oxidation of the surface of the nozzle, which is subjected to high temperatures in the combustion chamber.

Definite criteria for the extent to which the temperature of the tip end of the nozzle should be reduced are not disclosed. There is a generality-like criterion that the lower the temperature of the nozzle tip end, the higher the durability and reliability of the injection valve.

Examples of a first prior art technique are an electromagnetic fuel injection valve (Japanese Patent Application Laid-open (kokai) No. 62-103456) shown in FIG. 13 and a fuel injection valve (Japanese Patent Application Laid-open (kokai) No. 63-151970) shown in FIG. 14. Both of these inventions are intended to improve the heat radiation characteristics of the tip end of the injection valve N so as to reduce the temperature of the tip end of the fuel injection valve by providing the tip end of the injection valve N with a shroud S having a high heat conductivity.

An example of a second prior technique is a cooling structure of an injection nozzle shown in FIG. 15 (Japanese Utility Model Publication (kokoku) No. 8-5336). This structure is intended to cool a nozzle N by placing in the vicinity of the nozzle N a packing P capable of circulating a cooling fluid.

An example of a third prior art technique is a heat radiation member of a fuel injection nozzle of an internal-combustion engine shown in FIG. 16 (Japanese Patent Publication (kokoku) No. 63-65823). This heat radiation member is intended to improve the heat radiation characteristics of the tip end of the nozzle N by providing an elastically deformable seal lip L at the tip end of a bush.

An example of fourth prior art technique is a cylinder head for use in a diesel engine shown in FIG. 17 (Japanese Patent Publication (kokoku) No. 59-1103). This invention is intended to provide an engine head H which shields a nozzle from heat. This illustrative fourth example is directed toward improving the durability and reliability of an injection valve of a direct-injection high supercharging diesel engine, as well as to a technique for accomplishing the foregoing objects (1) through (3).

The examples of the first prior art technique are directed toward providing the tip end of the injection valve N with the shroud S having a high heat conductivity. However, the flow of heat within the injection valve N fitted to the engine has not been elucidated. In spite of the fact that the invention is intended to reduce the temperature of the injection valve N by providing the injection valve N with the shroud S having a high heat conductivity, the location of the engine to which the injection valve N is fitted is not specified, so that a heat flow path is not defined. Consequently, the improvements or advantageous effects of the invention cannot be specified. Depending on conditions in which the injection valve N is fitted to the engine, there may be no substantial effect of reducing temperatures, or there may arise an increase in the temperature of the injection valve.

In the example of the second prior art technique, the packing P capable of circulating a cooling fluid is placed in the vicinity of the nozzle N. According to the structure shown in FIG. 15, the packing P is located away from the tip end of the nozzle N, therefore resulting in a small effect of reducing the temperature of the tip end of the nozzle N. Since forming a cooling path up to the vicinity of the injection valve involves difficulties in terms of manufacture of an engine head, it is difficult to say that the invention has a high degree of practicality.

In the example of the third prior art technique, the thermal insulation characteristics of the tip end of the nozzle N is improved by providing the elastic deformable seal lip L at the tip end of the bush. The seal lip L is a simple heat insulation member and consequently has a high degree of practicality. Since the material of the seal lip L is limited to elastic metal, the heat conductivity

of the heat insulation member is equal to or greater than that of the nozzle. Although the heat insulation member has a function of facilitating flow of heat, it is hard to say that the function is sufficient. The heat insulation member does not have such a heat insulating effect as to interrupt or partially suppress the flow of heat.

The example of the third prior art technique also fails to provide a sufficient function of facilitating flow of heat from the nozzle N to the engine head. The most important matter to reduce the temperature of the nozzle through use of a member having a high heat conductivity is to reduce the heat resistance between the nozzle and the engine head to as low a value. The member is press-fitted onto the nozzle, so that the contact resistance of the heat flow path is reduced. However, in other areas, there are clearances between the nozzles and the engine head, or the nozzles and the engine head are only in slight contact with each other. Since there are no active efforts for reducing the heat resistance of other areas, the temperature of the tip end of the nozzle therefore cannot be reduced effectively with such an arrangement. Particularly, since the side surface of the nozzle has a wide area, it is very important to improve the heat radiation characteristics of the nozzle by reducing the contact resistance of the side surface of the nozzle.

In the example of the fourth prior art technique, the engine head H shields the nozzle N from heat. However, it is not intended to prevent the flow rate of fuel from decreasing as a result of accumulation of deposits on the internal surface of the nozzle hole of the injection valve. This can be seen from the fact that a protuberance formed at the tip end of the nozzle is exposed to the combustion chamber through a thermal insulation plate. The embodiment section of the patent describing the fourth example does not include any descriptions related to the position of the nozzle hole. However, in the case of this type of injection valve, it is publicly known that the nozzle hole is formed in the protuberance at the front end of the nozzle, due to the function of the nozzle hole. If the nozzle hole is formed in this position, the temperature of the tip end becomes higher than a 90%-distillation temperature of fuel. Therefore, deposits are accumulated on the internal surface of the nozzle hole, thereby resulting in a reduction in the flow rate of the injection valve.

SUMMARY OF THE INVENTION

It is a general object of the present invention to provide a deposit reduction fuel injection valve wherein the reduction of variations in a flow rate by suppression of the generation and accumulation of deposits on the internal surface of the nozzle hole. It is another object of the present invention to provide a deposit reduction fuel injection valve comprising a fuel injection valve which has a nozzle hole formed so as to face a combustion chamber of an internal combustion engine and which directly injects and supplies fuel to the combustion chamber, the temperature of the tip portion of a nozzle body having the nozzle hole formed thereon is adjusted by temperature adjusting means so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel, thereby holding in a liquid phase the fuel which remains on the internal surface of the nozzle hole after having been injected.

It is still another object of the present invention to provide a deposit reduction fuel injection valve wherein a heat flow path for dissipating heat from the nozzle body to the engine head is formed by heat flow formation means formed between the nozzle body and the engine head.

It is a further object of the present invention to provide a deposit reduction fuel injection valve wherein the nozzle body is shielded from the heat supplied from the combustion chamber, by a heat insulation member provided at the nozzle body.

An objection of the present invention is to solve the problem of a reduction in the flow rate of the injection valve as previously described. More specifically, the present invention is directed toward a deposit reduction fuel injection valve comprising a fuel injection valve which has a nozzle hole formed so as to face a combustion chamber of an internal combustion engine and which directly injects and supplies fuel to the combustion chamber, wherein there is prevented a phenomenon of a flow rate of fuel being reduced by a decrease in the area of the nozzle hole as a result of accumulation of deposits on the internal surface of the nozzle hole, by a reduction in lowering the temperature of the tip portion of the nozzle body so as to be lower than the 90%-distillation temperature of fuel to be used.

In the event that the temperature of the tip portion of the nozzle body of the injection valve becomes higher than the 90%-distillation temperature of fuel, there arises a recognizable reduction in the flow rate of the injection valve. This problem is more apt to occur in a fuel injection valve used in a direct gasoline injection engine which consumes gasoline having a 90%-distillation temperature lower than that of gas oil.

Circumstances under which the flow rate of the injection valve is reduced will be described hereinbelow.

Through use of fuel having a 90%-distillation temperature of 150°C, the inventors of the present invention performed an engine test for 30 hr. at an air-to-fuel ratio of 12 in which the tip portion of the nozzle body reaches 165°C after 30 min. have elapsed since the commencement of the engine test. FIG. 9 shows the manner in which the flow rate of the injection valve decreases at that time. The flow rate abruptly decreases until ten hours elapse from the commencement of the test. Although there is no further reduction in the flow rate after lapse of 10 hr., the rate of reduction of the flow rate reaches 10% when the test is completed.

After observation of the internal surface of the nozzle hole of the injection valve nozzle, deposits are

acknowledged to have been accumulated as a result of carbonization. From the result of this observation, it is understood that deposits cause a reduction in the area of the nozzle hole and a reduction in the flow rate of the injection valve.

The inventors examined the manner in which the flow rate of the injection valve was reduced by performing an engine test similar to that illustrated in FIG. 9 for 30 hr. on condition that the temperature of the tip portion of the nozzle body was decreased so as to be maintained lower than 165°C. The results of such an engine test are illustrated in FIG. 10. On condition that the temperature of the tip portion of the nozzle body is 155°C, the rate of reduction in the flow rate is about 3%. In contrast, on condition that the temperature of the tip portion of the nozzle body is reduced to 100°C, the rate of reduction in the flow rate becomes about 1%.

The mechanism of occurrence of the phenomenon is described below. FIG. 3 schematically illustrates the occurrence of the phenomenon.

Fuel contains precursors of deposit which will serve as the nucleus of deposits during the course of generation of the deposits. At room temperature, these precursors of deposit are dispersed in the fuel.

After having been injected, the fuel remains in trace amounts on the internal surface of the nozzle hole. If the temperature of the tip portion of the nozzle body is lower than the 90%-distillation temperature of the fuel (150°C), the fuel remaining on the internal surface of the nozzle hole is held in a liquid phase. Accordingly, the precursors of deposit contained in the fuel also remain dispersed in the fuel. The precursors of deposit remaining in the dispersed state are easily flushed away together with the fuel by the next injection, thereby suppressing the generation of deposits on the internal surface of the nozzle hole.

In contrast, on condition that the temperature of the tip portion of the nozzle body is higher than the 90%-distillation temperature (150°C), evaporation of the fuel remaining inside the nozzle hole is promoted. Therefore, the precursors of deposit cannot remain in the dispersed state in the fuel, so they aggregate on the internal wall surface of the nozzle hole. In such a state, it is difficult to flush the thus-aggregated precursors of deposit away at the time of the next injection, so they remain in the nozzle hole. As a result, the accumulation of deposits proceeds.

From these tests, the inventors of the present invention have learned that, in order to suppress the generation of deposits on the internal surface of the nozzle hole, it is necessary to reduce the temperature of the tip portion of the nozzle body so as to maintain the temperature lower than a 90%-distillation temperature of the fuel, to constantly hold the fuel remaining on the internal surface of the nozzle hole in a liquid phase, thereby maintaining precursors of deposit dispersed in the fuel.

Further, the inventors have learned that the formation of the following heat flow path is useful for accomplishing the foregoing requirements. Specifically, the heat flow path is formed by inserting a substance having a high heat conductivity between the side surface of the nozzle and the engine head so as to minimize the contact resistance between the side surface and the substance and between the substance and the engine head. By virtue of this heat flow path, the heat resistance between the side surface of the nozzle body and the engine head is reduced, and the heat supplied to the nozzle body as a result of convection or radiation of a combustion gas is easily dissipated to the engine head.

The inventors of the present invention also learned important factors in suppressing the reduction in the flow rate of the injection valve by having performed another test from different viewpoints. The temperature history of the tip portion of the nozzle body was measured under the same conditions as those shown in FIG. 9. Further, the injection valve was removed from the engine head after lapse of 3, 7, 15, and 30 hours, and the thickness of soot built up on the surface of the nozzle body was determined. The result of such determination is shown in FIG. 11.

The temperature of the tip portion of the nozzle body, which is 180°C immediately after the commencement of the engine test, drops to 165°C after the lapse of 30 min. since the commencement of the test. The temperature of the tip portion of the nozzle body decreases with the lapse of time, and the temperature drops to about 130°C after the lapse of 15 hr. In contrast, the thickness of the soot built up on the surface of the nozzle body increases with the lapse of time, and the thickness reaches 0.34 mm after the lapse of 15 hr. However, a phenomenon is observed in which the temperature of the tip portion of the nozzle body sharply increases immediately before the operating time of the engine reaches 30 hr. It has been ascertained that the soot has been scraped off from the surface of the nozzle body, so that the metallic base material of the nozzle body is exposed. From the results of this test, it is understood that the reduction in the temperature of the tip portion of the nozzle body has strong relevancy to the soot accumulated on the surface of the nozzle body. In short, it is concluded that the soot forms a thermal insulation layer which suppresses the flow of heat supplied to the nozzle body from the combustion chamber.

After continuation of the engine test, a reduction in the temperature of the tip portion of the nozzle body was again ascertained.

In reference to the result of measurement of the temperature of the nozzle tip portion, the variations in the flow rate shown in FIG. 9 are reviewed. A lack of progress in the reduction of the flow rate after the lapse of 8 hr since commencement of the test is considered to be ascribed to the fact that the temperature of the tip portion of the nozzle body has already been dropped as a result of accumulation of soot.

In this way, if the soot is built up on the surface of

the nozzle body, the soot serves as a heat insulation layer which reduces the temperature of the nozzle body. Therefore, it is understood that the soot suppresses the progress of the reduction of the flow rate of the injection valve.

It is a still further object of the present invention to provide a deposit reduction fuel injection valve comprising a nozzle hole, formed on a tip portion of a nozzle body so as to face a combustion chamber of an internal combustion engine, for injecting directly fuel in the combustion chamber, and a temperature adjusting means for adjusting a temperature of the tip portion of the nozzle body having the nozzle hole so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel.

It is a yet further object of the present invention to provide a deposit reduction fuel injection valve wherein the temperature adjusting means comprises a heat flow formation means formed between the nozzle body having the nozzle hole formed thereon and an engine head for dissipating a heat in the nozzle body to the engine head.

It is a yet further object of the present invention to provide a deposit reduction fuel injection valve wherein the heat flow formation means comprises a heat conduction promoting member which is formed from a material having a high heat conductivity and is interposed between an internal wall surface of the engine head and an outer side surface of the nozzle body, and the heat conduction promoting member reduces a heat resistance between the nozzle body and the engine head, so that the dissipation of the heat flow supplied to the nozzle body toward the engine head is promoted.

A deposit reduction fuel injection valve of the present invention is directed toward a fuel injection valve comprises a nozzle body which has a nozzle hole formed thereon so as to face a combustion chamber of an internal combustion engine and which directly injects and supplies fuel to the combustion chamber. With regard to a nozzle body having the nozzle hole of the injection valve formed thereon, a heat flow path is formed by inserting a substance having a high heat conductivity between the side surface of the nozzle body and the engine head so as to minimize the contact resistance between the side surface and the substance and between the substance and the engine head. By virtue of this heat flow path, the heat resistance between the nozzle body and the engine head is reduced, and the heat supplied to the nozzle body as a result of convection or radiation of a combustion gas becomes easily dissipated to the engine head. An area of the nozzle body exposed in the combustion chamber or part of this area of the nozzle body is covered with a substance having a low heat conductivity so as to interrupt or suppress the inflow of heat supplied to the nozzle body from the combustion chamber. The temperature of the tip portion of the nozzle body is reduced so as to become lower than a 90%-distillation temperature of fuel, so that the fuel remaining on the internal surface of the nozzle hole after having been injected is maintained in a liquid phase.

It is another object of the present invention to provide a deposit reduction fuel injection valve wherein the temperature adjusting means comprises a heat insulation member which is formed from a material having a low heat conductivity and which is provided in at least part of an area of the tip portion of the nozzle body exposed to the combustion chamber so as to insulate heat supplied from the combustion chamber to the nozzle body.

The accumulation of soot differs according to the engine specifications and driving conditions, and there is also such a case as shown in FIG. 11 where the soot is scraped off from the nozzle body. Therefore, in some cases, accumulated soot may not serve as a permanent measure to maintain the temperature of the tip portion of the nozzle body at a temperature lower than the 90%-distillation temperature. For this reason, in order to stably maintain the temperature of the tip portion of the nozzle body at a temperature lower than the 90%-distillation temperature of the fuel, it is effective to attach a heat insulation material to the tip portion of the nozzle body so as to interrupt the flow of heat into the nozzle body as a result of convection or radiation of a combustion gas.

It is a further object of the present invention to provide a deposit reduction fuel injection valve wherein a ratio of heat conductivity λ(W/mm/K) to a thickness "t" (mm) of the heat insulation member; i.e., λ/t, is set so as to be smaller than 8.5×10^{-4}.

It is a yet further object of the present invention to provide a deposit reduction fuel injection valve wherein the heat insulation member is provided on a lower edge of the tip portion of the nozzle body so as to annularly surround the nozzle hole.

It is a yet further object of the present invention to provide a deposit reduction fuel injection valve wherein an outlet of the nozzle hole is positioned above a lowermost end of the heat insulation member.

In the deposit reduction fuel injection valve according to the present invention, a nozzle hole is formed to face a combustion chamber of an internal combustion engine so as to directly inject and supply fuel to the combustion chamber. The temperature adjusting means having the nozzle hole formed thereon adjusts the temperature of the tip portion of the nozzle body so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel, thereby suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole and hence resulting in reduced variations in a flow rate.

In the deposit reduction fuel injection valve according to the present invention, which has the foregoing structure and depends on the first invention, the heat flow formation means formed between the engine head and the nozzle body having the nozzle hole, which con-

stitutes the temperature adjusting means, dissipates heat supplied to the nozzle body to the engine head. Therefore, the temperature of the tip portion of the nozzle body is reduced so as to be maintained lower than the 90%-distillation temperature of fuel by controlling the heat flow from the nozzle body to the engine head, thereby suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole and hence resulting in effective reduction of variations in a flow rate.

In the deposit reduction fuel injection valve according to the present invention, a heat conduction promoting member, which is formed from a material having a high heat conductivity and is interposed between the internal wall surface of the engine head and the outer side surface of the nozzle body constituting the heat flow formation means, reduces the heat resistance between the nozzle body and the engine head, so that the dissipation of the heat supplied to the nozzle body toward the engine head is promoted. As a result, the flow of heat from the nozzle body to the engine head is promoted, so that the temperature of the tip portion of the nozzle body is reduced so as to be maintained lower than or equal to the 90%-distillation temperature of the fuel, thereby suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole and hence resulting in effective reduction of variations in a flow rate.

Specifically, the heat flow path is formed by inserting a substance having a high heat conductivity between the side surface of the nozzle and the engine head, thereby reducing the heat resistance between the side surface of the nozzle and the engine head. As a result, the heat flowing into the nozzle can be easily dissipated to the engine head. The operation and effects of this heat flow path will be described in detail hereinbelow.

The heat resulting from the convection or radiation of the combustion gas is supplied to the tip portion of the nozzle body exposed in the combustion chamber, thereby increasing the temperature of the tip portion of the nozzle body. Heat flows into the engine head, which has a comparatively lower temperature, via the area whose heat resistance has been reduced. If the present invention is not applied to the engine, the heat principally flows to the engine head via screws and a gasket which fit the injection valve to the engine head.

Since these screws and gasket are usually provided in an upper part of the nozzle body, a very small effect of reducing the temperature of the nozzle tip portion will be expected even if an attempt is made to reduce the heat resistance of the screws and gasket. For this reason, in order to efficiently reduce the temperature of the tip portion of the nozzle body, necessary to form a new heat flow path for guiding the heat flow from the nozzle body to the engine head by inserting a member having a high heat conductivity between the side surface of the nozzle body and the engine head in a state in which the contact resistance becomes as small as possible. As a result, the heat supplied to the nozzle body easily flows to the engine head having a comparatively lower temperature, enabling effective reduction of the temperature of the tip portion of the nozzle body.

The inventors of the present invention have quantitatively studied a method of effectively inserting the member having a high heat conductivity between the nozzle body and the engine head. FIG. 1 illustrates one embodiment of the present invention, wherein a copper sleeve 60 is inserted between a tip portion 8 of a nozzle body and an engine head 4. As a result, the thermal contact resistance between the side surface of the tip portion 8 of the nozzle body and the copper sleeve 60, as well as that between the copper sleeve 60 and the engine head 4, is substantially reduced to zero.

In contrast, FIG. 12 shows an injection valve analogous to the conventional injection valve shown in FIG. 16. An air layer is formed in an area S indicated by a dashed line, and temperatures of the tip portions of these nozzles are compared with each other in FIG. 2.

The temperature of the tip portion of the nozzle body of the present invention is 135°C, and there is obtained a reduction in temperature as large as 45°C relative to an injection valve (the temperature of the tip portion of the nozzle body is 180°C) which does not have the copper sleeve 10 inserted therein. In the case of the injection valve analogous to the conventional injection valve, as is evident from FIG. 2, the temperature of the tip portion of the nozzle body is 150 reduction effect as compared to that of the present invention.

In the deposit reduction fuel injection valve according to the present invention, the heat insulation member, which is formed from a material having a low heat conductivity and which is provided in at least part of the area of the nozzle body exposed to the combustion chamber, shields the nozzle body from the heat supplied from the combustion chamber. Accordingly, the temperature of the tip portion of the nozzle body is reduced so as to be maintained lower than the 90%-distillation temperature of fuel, thereby more effectively suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole and hence resulting in further effective reduction of variations in a flow rate.

The heat insulation member according to the fourth invention, is formed from a substance having a low heat conductivity and covers the area of the nozzle body exposed to the combustion chamber or a part of that area. The operation and effects of this heat insulation member when it shields the nozzle body from the heat flowing from the combustion chamber will be described.

If the area of the fuel injection valve nozzle body exposed to the combustion chamber or part of that area is covered with a substance having a low heat conductivity, the amount of heat flowing into the tip portion of the nozzle body becomes smaller, enabling reductions in the temperature of the tip portion of the nozzle body.

In the deposit reduction fuel injection valve according to the fifth invention, which has the foregoing structure and depends on the fourth invention, the ratio of heat conductivity λ(W/mm/K) of the material constituting the thermal insulation member to the thickness "t" (mm) of the thermal insulation member; i.e., λ/t, is set to b smaller than 8.5×10^{-4}. As a result, there is produced an effect of adjusting the temperature of the tip portion of the nozzle body in an optimum way so that the temperature is maintained equal to or lower than the 90%-distillation temperature of fuel.

The effect of reducing the temperature of the tip portion of the nozzle body is dependent on the heat conductivity of the area of the nozzle body exposed to the combustion chamber or of a member attached to a part of the exposed area. A trial calculation was made with regard to the heat conductivity of the member attached to the exposed area of the nozzle body inserted in the combustion chamber, as well as to the effect of reducing the temperature of the tip portion of the nozzle body obtained when the thickness of the member was changed. FIG. 8 illustrates the results of such trial calculation. Here, boundary conditions are set such that the temperature of the tip portion of the nozzle body becomes 180°C when the tip portion is directly exposed to the combustion chamber.

If a member having a heat conductivity of 1×10^{-3} W/mm is used, the temperature of the tip portion of the nozzle becomes 168°C, provided that the thickness of the member is 0.35 mm. The temperature is reduced to 150°C with a thickness of 1.2 mm, 140°C with a thickness of 2 mm, and to 130°C with a thickness of 4 mm. The lower the heat conductivity of the member, the thinner the thickness of the member can be made. If the ratio of the heat conductivity λ(W/mm/K) of the member attached to the exposed area of the nozzle body in the combustion chamber to the thickness "t" (mm) of the member; i.e., λ/t, is set so as to be smaller than 8.5×10^{-4}, the temperature of the tip portion of the nozzle body can be maintained at a temperature lower than or equal to 150°C. This temperature is lower than the 90%-distillation temperature of ordinary gasoline. In this type of injection valve, the generation and accumulation of deposits on the internal surface of the nozzle hole are suppressed, thereby enabling implementation of an injection valve which reduces variations in its flow rate.

In the deposit reduction fuel injection valve according to the present invention, the thermal insulation member is annularly provided at the lowermost end of the nozzle body so as to surround the nozzle hole. Therefore, the deposit reduction fuel injection valve has an effect of effectively shielding the nozzle body from the heat supplied from the combustion chamber.

In the deposit reduction fuel injection valve according to the present invention, an outlet of the nozzle hole is positioned above the lowermost end of the thermal insulation member. Therefore, the outlet of the nozzle hole does not project into the combustion chamber, and there is produced an effect of reducing the amount of deposit to b deposited because the outlet port is set back from the combustion chamber.

Attention should be also given to the positional relationship between such a substance having a low heat conductivity and the outlet f the nozzle hole. The outlet of the nozzle hole does not project into the combustion chamber and is positioned above the lowermost end of the thermal insulation member made of the material of low heat conductivity. With this arrangement, the thermal insulation member is utilized to prevent the nozzle hole from being directly exposed to heat in the same manner as a breakwater is utilized to protect a pier from waves, thereby suppressing accumulation of deposits on the internal surface of the nozzle hole.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross section illustrating a deposit reduction fuel injection valve according one embodiment of the present invention;

FIG. 2 is a diagram illustrating the temperatures of the tip portions of the nozzle of the present invention and a conventional nozzle body;

FIG. 3 is an explanatory representation illustrating the processes of generation of deposits on the fuel injection valve;

FIG. 4 is a diagram illustrating the relationship between a heat conductivity and the temperature of the tip portion of the nozzle body;

FIG. 5 is a cross section illustrating a deposit reduction fuel injection valve according to a first embodiment of the present invention;

FIG. 6 is a cross section illustrating a deposit reduction fuel injection valve according to a second embodiment of the present invention;

FIG. 7 is a cross section illustrating a deposit reduction fuel injection valve according to a third embodiment of the present invention;

FIG. 8 is a cross section illustrating a deposit reduction fuel injection valve according to a fourth embodiment of the present invention;

FIG. 9 is a diagram illustrating the relationship between an operating time of the engine and the rate of reduction in a flow rate;

FIG. 10 is a diagram illustrating the relationship between the temperature of the tip portion of the nozzle body and the rate of reduction in the flow rate;

FIG. 11 is a diagram illustrating the relationship between an operating time of the engine, the temperature of the tip portion of the nozzle body, and the thickness of accumulation of soot;

FIG. 12 is cross section illustrating a conventional nozzle body to be compared with the nozzles body of the present invention;

FIG. 13 is a cross section of an electromagnetic fuel injection valve, which is an example of a first prior

art technique;

FIG. 14 is a cross section of a fuel injection valve, which is another example of the first prior art technique;

FIG. 15 is a cross section illustrating a cooling structure of an injection valve, which is an example of a second prior art technique;

FIG. 16 is a cross section of a heat insulation member of a fuel injection nozzle of an internal-combustion engine, which is an example of a third prior art technique; and

FIG. 17 is a cross section illustrating part of a cylinder head of a diesel engine, which is the example of the third prior art technique.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the drawings, embodiments of the present invention will be described.

First Embodiment

As illustrated in FIG. 5, a deposit reduction fuel injection valve according to a first embodiment of the present invention comprises a fuel injection valve 1 which has a nozzle hole 3 formed on a lower tip end of a tip portion 8 of a nozzle body so as to face a combustion chamber 2 of an internal-combustion engine and which directly feeds fuel to the combustion chamber. A temperature adjusting means 5 for adjusting the temperature of the tip portion 8 of the nozzle body having the nozzle hole 3 formed thereon so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel is formed between the tip portion 8 of the nozzle body having the nozzle hole 3 formed thereon and an engine head 4. The deposit reduction fuel injection valve further comprises a heat flow formation means 6 which dissipates heat supplied to the nozzle 8 to the engine head 4.

The engine head 4 is provided with a cooling path for circulating cooling water, whereby the temperature of the engine head 4 is maintained at about 80°C.

In the first embodiment, the injection valve 1 is fixed to the engine head 4 via an injection valve fixing jig 11. A plurality of holes are formed in the fixing jig 11, and bolts are screwed into these holes. The bolts are fitted to the engine head 4. As a result, forces to fasten the bolts are exerted on the engine head 4 via the fixing jig 11, the injection valve flange 12, and the gasket 13, whereby the injection valve 1 is fixed to the engine head 4.

The combustion chamber 2 is formed from a space which is surrounded by the engine head 4, a cylinder, and a piston (not shown). A mixed gas consisting of fuel and air is combusted within the combustion chamber 2 thereby to produce a large quantity of heat.

The heat flow formation means 6 ensures a new path over which heat flows from the tip portion 8 of the nozzle body to the engine head 4. The heat flowing into the tip portion 8 of the nozzle body can be easily dissipated to the engine head 4. A heat conduction promoting member 60 is formed from a material having a high heat conductivity and is disposed between the outer side surface of a cylindrical base portion of the tip portion 8 of the nozzle body and the inner wall surface of the engine head 4. By virtue of this heat conduction promoting member 60, the heat resistance between the nozzle 8 and the engine head 4 is reduced to thereby promote dissipation of the heat flowing to the nozzle 8 to the engine head 4.

The heat conduction promoting member 60 is formed from a hollow cylindrical copper sleeve 61 whose base material is copper having a high heat conductivity. The copper sleeve 61 is formed so as to have given inner and outer diameters and is disposed between an outer circumferential surface 81 of the tip portion 8 of the nozzle body and an inner circumferential surface of a nozzle insertion hole 41 of the engine head 4. The heat conduction promoting member 60 is inserted into the annular space formed between the nozzle 8 and the nozzle insertion hole 41 of the engine head 4.

The sleeve 61 has its inner circumferential surface held in close contact with the outer circumferential surface 81 of the cylindrical base portion of the tip portion 8 so as to minimize the heat resistance of the contact surface between the inner circumferential surface 81 of the sleeve 61 and the outer circumferential surface of the nozzle 8. The outer circumferential surface of the copper sleeve 61 is brought into close contact with the inner circumferential surface of the engine head 4, thereby minimizing the heat resistance of the contact surface between them.

In the deposit reduction fuel injection valve according to the first embodiment having the foregoing structure, the copper sleeve 61, which is made of a material having a high heat conductivity and constitute the heat conduction promoting member 60, is inserted between the side surface 81 of the nozzle 8 and the engine head 4, so that a heat flow path is formed while the heat resistance between the side surface 81 of the nozzle 8 and the engine head 4 is minimized. As a result, the heat flowing into the nozzle 8 is dissipated to the engine head 4.

In the deposit reduction fuel injection valve according to the first embodiment which operates in the above described manner, a new path over which heat flows from the nozzle 8 to the engine head 4 is ensured. The heat flowed into the nozzle 8 is effectively dissipated to the engine head 4, thereby reducing the temperature of the tip portion 8 of the nozzle body having the nozzle hole 3 formed therein. As a result, the fuel is in the liquefied state on the inner surface of the nozzle hole 3, thereby suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole 3

and hence resulting in reduced variations in a flow rate.

The operation and effects of the deposit reduction fuel injection valve according to the first embodiment are stably ensured even when the injection valve 1 is fitted to the engine 4 utilizing screws provided on the injection valve 1, without use of the fixing jig 11 in the first embodiment.

Second Embodiment

As shown in FIG. 6, a deposit reduction fuel injection valve according to a second embodiment is different from that of the first embodiment in that an outer circumferential surface 621 of the copper sleeve 62 and the inner circumferential wall of the engine head 4 are tapered in order to increase the degree of close-contact between the copper sleeve 62, which comes into contact with the Side surface 81 of the tip portion 8 of the nozzle body, and the inner circumferential wall of the engine head 4. The difference is principally described hereinbelow.

With regard to the copper sleeve 62 inserted between the nozzle 8 and the engine head 4, it is necessary to minimize thermal contact resistance between the nozzle 8 and the copper sleeve 62, as well as between the copper sleeve 62 and the engine head 4.

As a result of tapering the outer circumferential wall of the copper sleeve 62 and a nozzle insertion hole 41 of the engine head 4 for receiving the copper sleeve 62, the copper sleeve 62 is sandwiched between and held in close contact with the engine head 4 and the nozzle 8 in a wedge-like manner when the injection valve 1 is fitted to the engine head 4.

In the deposit reduction fuel injection valve of the second embodiment having the foregoing structure, the surfaces of the copper sleeve 61 and the engine head 4 which are in contact with each other are tapered, and they are brought into close contact with each other in a wedge-like manner. A heat flow path whose contact resistance is minimized is provided between the nozzle 8 and the engine head 4, thereby facilitating the dissipation to the engine head 4 of the heat flowing to the tip portion 8 of the nozzle body.

In the deposit reduction fuel injection valve of the second embodiment which operates in the foregoing way, the surfaces of the copper sleeve 61 and the engine head 4 which are in contact with each other are tapered, so that the close contact state is improved, and the contact area between the copper sleeve and the engine head is increased. As a result, there is produced an effect of drastically reducing the thermal contact resistance of the contact surfaces, so that the temperature of the tip portion of the nozzle is efficiently reduced.

The above-described effect can be obtained by tapering the surfaces of the nozzle 8 and th copper sleeve which are in contact with each other, or by tapering the surfaces of the nozzl 8, the copper sleeve 62, and the engine head 4 which are in contact with each other.

Third Embodiment

A deposit reduction fuel injection valve according to a third embodiment is different from that in the first embodiment in the following point. Namely, as illustrated in FIG. 7, in addition to the heat conduction promoting member 60 which is made of a material having a high heat conductivity and which is interposed between the side surface of the tip portion 8 of the nozzle body and the engine head 4, the deposit reduction fuel injection valve is provided with a heat insulation member 7 which is provided on the area of the nozzle 8 exposed in the combustion chamber 2 and which shields the nozzle 8 from heat fed from the combustion chamber 2. The difference is principally described hereinbelow.

The copper sleeve 61 which contains copper having a high heat conductivity as a base material is inserted between the nozzle 8 and the engine head 4. The tapered-tip portion of the nozzle 8, which is exposed to the combustion chamber 2, is covered with the annular heat insulation member 7 having a low heat conductivity. A circular hole is formed at the center of the heat insulation member 7 so as to constitute the nozzle hole 3 having a given axial length.

In the deposit reduction fuel injection valve of the third embodiment having the foregoing structure, a heat flow path is formed between the side surface of the nozzle 8 and the engine head 4 by the copper sleeve 61, which serves as the heat conduction promoting member 60 in a state in which the heat resistance between the side surface of the nozzle 8 and the engine head 4 is minimized, enabling facilitation of dissipation to the engine head 4 of the heat flowing into the nozzle. The exposed area of the nozzle 8 in the combustion chamber 2 is covered with the heat insulation member 7 which is made of a material having a low heat conductivity, thereby interrupting or regulating the heat flowing to the nozzle 8 from the combustion chamber 2.

In the deposit reduction fuel injection valve of the third embodiment which operates in the foregoing way, the copper sleeve 61 is brought into close contact with the nozzle 8 and the engine head 4, minimizing the heat resistance of the contact surfaces between them. Further, the heat supplied to the tip portion of the nozzle 8 from the combustion chamber 2 can be substantially interrupted by the heat insulation member 7. More specifically, not only the dissipation of heat from the nozzle 8 but also interruption of entry of the heat to the nozzle 8 are effected, and the temperature of the tip portion of the nozzle 8 is therefore reduced more efficiently, thereby effectively suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole 3 and hence resulting in reduced variations in a flow rate.

Fourth Embodiment

A deposit reduction fuel injection valve according to a fourth embodiment is different from that of the first embodiment in that the tip portion 8 of the nozzle body has a two-staged structure as illustrated in FIG. 8; namely, a structure comprising a base large-diameter section 84 and a tip small-diameter section 85, and in that a thin tube-like copper sleeve 64 is brought into contact with the outer circumferential surface of the base large-diameter section 84, as well as with the overall inner circumferential wall of the nozzle insertion hole of the engine head 4. A heat insulation member 94 having a low heat conductivity is interposed between a tip end of the tip small-diameter section 85 and the copper sleeve 64.

The copper sleeve 64 has its lower edge bent in a radially inward direction of the nozzle 8 at a position corresponding to the lower end of the inner circumferential wall of the nozzle insertion hole of the engine head 4. An annular hole is formed at the center of the copper sleeve so as to constitute the nozzle hole 3 formed on a tip taper end of the tip portion 8 of the nozzle body

The heat insulation member 94 is provided so as to come into contact with the outer circumferential wall of the tip portion small-diameter section 85 of the nozzle 8 and its tapered lowermost end. A tapered circular hole is formed at the lower center of the copper sleeve in consideration of a spray pattern. The nozzle hole 3 of the nozzle 8 is positioned a predetermined distance above the lower end of the heat insulation member 94 (the circular hole of the copper sleeve 64).

In the deposit reduction fuel injection vale of the fourth embodiment having the foregoing structure, a heat flow path is formed between the side surface of the nozzle 8 and the engine head 4 by the copper sleeve 61, which serves as the heat conduction promoting member 60 in a state in which the heat resistance between the side surface of the nozzle 8 and the engine head 4 is minimized, enabling facilitation of dissipation to the engine head 4 of the heat flowing into the nozzle. The exposed area of the nozzle 8 in the combustion chamber 2 is covered with the heat insulation member 94 which is made of a material having a low heat conductivity, thereby interrupting or regulating the heat flowing to the nozzle 8 from the combustion chamber 2.

In the deposit reduction fuel injection valve of the fourth embodiment which operates in the foregoing way, the copper sleeve 64 is brought into close contact with the nozzle 8 and the engine head 4, minimizing the heat resistance of the contact surfaces between them. Further, the heat supplied to the tip portion of the nozzle 8 from the combustion chamber 2 can be interrupted substantially by the heat insulation member 94. More specifically, not only the dissipation of heat from the nozzle 8 but also interruption of entry of the heat to the nozzle 8 are effected, and the temperature of the tip portion of the nozzle 8 is therefore reduced more efficiently, thereby effectively suppressing the generation and accumulation of deposits on the internal surface of the nozzle hole 3 and hence resulting in reduced variations in a flow rate.

In the deposit reduction fuel injection valve of the fourth embodiment, the outlet of the nozzle hole 3 is positioned above the lowermost edge of the heat insulation member 94. Thus, since the outlet of the nozzle hole 3 does not project into the combustion chamber 2 but is set back from the same, there is produced an effect of reducing the amount of deposits to be accumulated.

Further, in the deposit reduction fuel injection valve of the fourth embodiment, the copper sleeve 64 has its lower edge inwardly folded over in the radial direction of the nozzle 8 at the lower end of the inner circumferential wall of the nozzle insertion hole of the engine head 4 so as to cover the lowermost outer periphery of the heat insulation member 94. The heat flowing to the heat insulation member 94 and the nozzle 8 from the combustion chamber 2 is interrupted, and the nozzle 8 is cooled and regulated by the copper sleeve 64 cooled by the engine head 4 which is cooled by the cooling water. Therefore, there is produced an effect of more efficiently reducing the temperature of the tip portion of the nozzle 8.

Through the engine test, the inventors verified that the fuel injection valve of the fourth embodiment could have reduced the temperature of the tip portion of the nozzle about 60°C relative to the conventional fuel injection valve.

The preferred embodiments of the present invention, as herein disclosed, are taken as some embodiments for explaining the present invention. It is to be understood that the present invention should not be restricted by these embodiments and any modifications and additions are possible so far as they are not beyond the technical idea or principle based on descriptions of the scope of the patent claims.

Although the fourth embodiment has been described with reference to the example in which the copper sleeve has its lower edge inwardly folded over so as to cover the nozzle and the heat insulation member, and in which the nozzle and the heat insulation member are cooled by utilization of the cooling water of the engine head, the present invention is not limited to this case. The present invention is also capable of adopting an embodiment in which the copper sleeve is fitted into the nozzle insertion hole of the engine head above the lowermost end of the nozzle insertion hole without folding over the lower edge of the copper sleeve. This structure prevents the copper sleeve from being exposed to the combustion chamber 2, while ensuring the maximum area for dissipating heat from the nozzle 8 to the engine head.

A deposit reduction fuel injection valve including a nozzle hole, formed on a tip portion of a nozzle body so as to face a combustion chamber of an internal combustion engine, for injecting directly fuel in said combustion

chamber, and a temperature adjusting system for adjusting a temperature of said tip portion of said nozzle body having said nozzle hole so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel.

Claims

1. A deposit reduction fuel injection valve comprising

   a nozzle hole, formed on a tip portion of a nozzle body so as to face a combustion chamber of an internal combustion engine, for injecting directly fuel in said combustion chamber, and
   a temperature adjusting means for adjusting a temperature of said tip portion of said nozzle body having said nozzle hole so as to maintain the temperature equal to or lower than a 90%-distillation temperature of fuel.

2. A deposit reduction fuel injection valve according to claim 1, wherein
   said temperature adjusting means comprises

   a heat flow formation means formed between said nozzle body having the nozzle hole formed thereon and an engine head for dissipating a heat in said nozzle body to said engine head.

3. A deposit reduction fuel injection valve according to claim 2, wherein
   said heat flow formation means comprises

   a heat conduction promoting member which is formed from a material having a high heat conductivity and is interposed between an internal wall surface of said engine head and an outer side surface of said nozzle body, and said heat conduction promoting member reduces a heat resistance between said nozzle body and the engine head, so that the dissipation of the heat flow supplied to said nozzle body toward said engine head is promoted.

4. A deposit reduction fuel injection valve according to claim 3, wherein
   said temperature adjusting means comprises

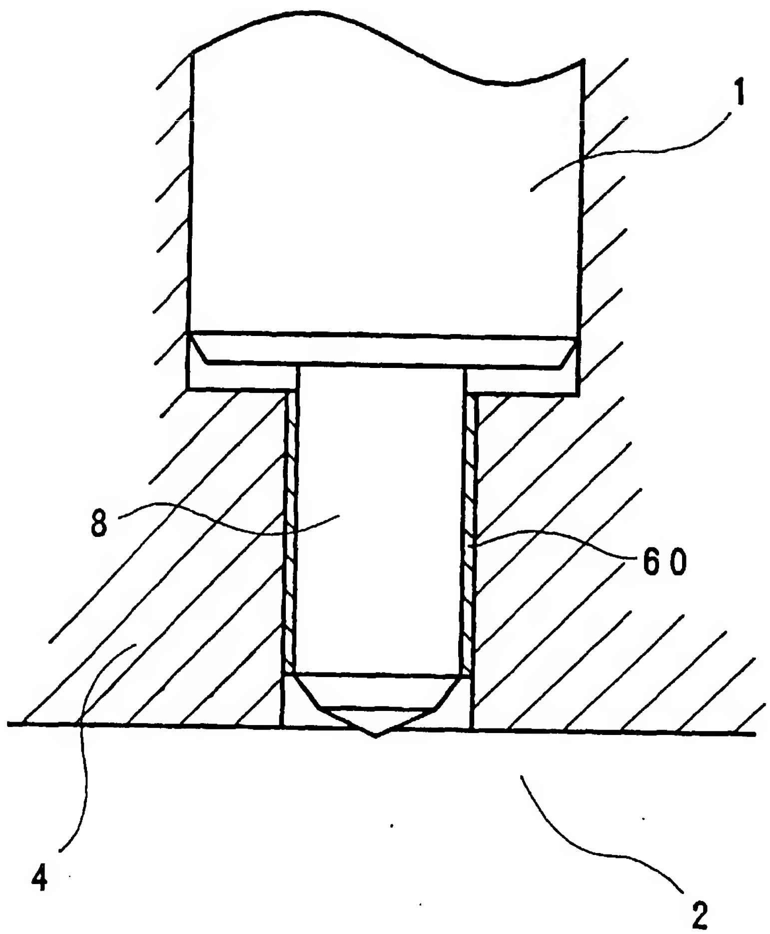
   a heat insulation member which is formed from a material having a low heat conductivity and which is provided in at least part of an area of said tip portion of said nozzle body exposed to said combustion chamber so as to insulate heat supplied from said combustion chamber to said nozzle body.

5. A deposit reduction fuel injection valve according to claim 4, wherein
   a ratio of heat conductivity λ(W/mm/K) to a thickness "t" (mm) of said heat insulation member; i.e., λ/t, is set so as to be smaller than 8.5×10^{-4}.

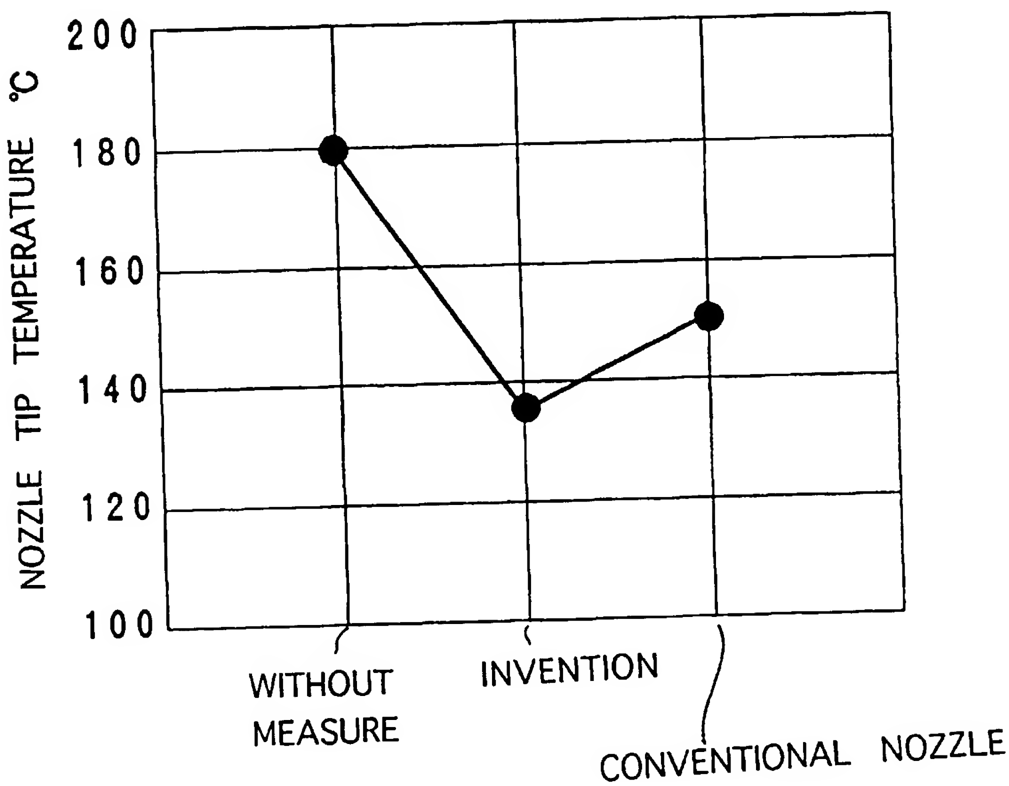
6. A deposit reduction fuel injection valve according to claim 5, wherein
   said heat insulation member is provided on a lower edge of said tip portion of said nozzle body so as to annularly surround said nozzle hole.

7. A deposit reduction fuel injection valve according to claim 6, wherein
   an outlet of said nozzle hole is positioned above a lowermost end of said heat insulation member.

FIG. 1

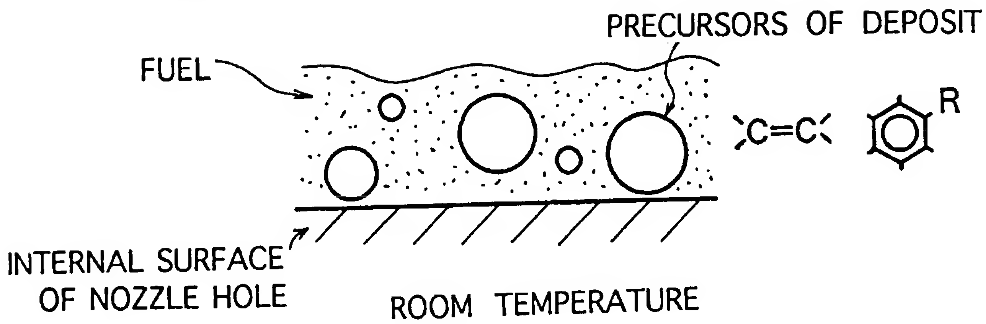


F I G. 2



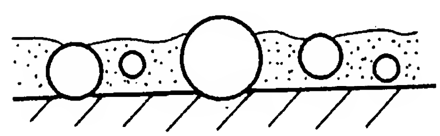
200
180
160
140
120
100
NOZZLE TIP TEMPERATURE °C
WITHOUT MEASURE
INVENTION
CONVENTIONAL NOZZLE

FIG. 3
(A)



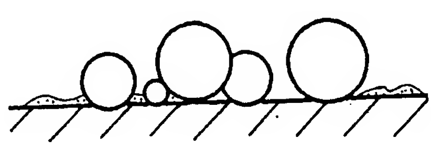
ROOM TEMPERATURE

FIG. 3
(B)



NOZZLE TEMPERATURE ≤ 90%-DISTILLATION TEMPERATURE

FIG. 3
(C)



NOZZLE TEMPERATURE > 90%-DISTILLATION TEMPERATURE

F I G. 4

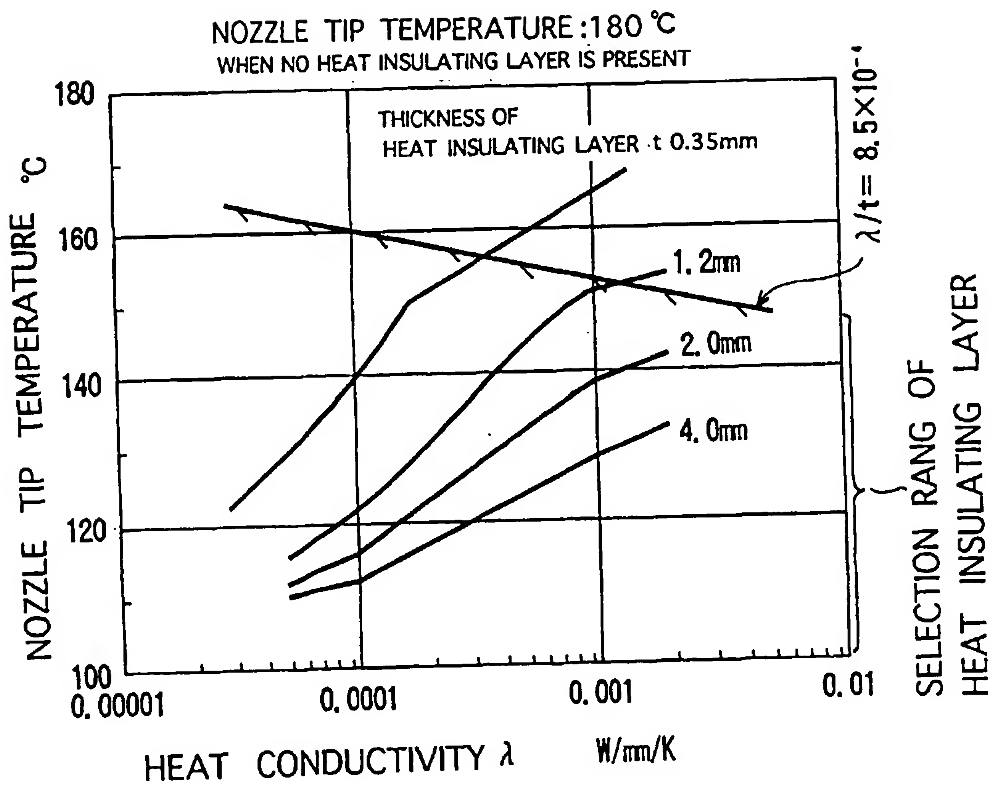

NOZZLE TIP TEMPERATURE :180 ℃
WHEN NO HEAT INSULATING LAYER IS PRESENT
THICKNESS OF
HEAT INSULATING LAYER t 0.35mm
1. 2mm
2. 0mm
4. 0mm
λ/t= 8.5×10⁻⁴
SELECTION RANG OF
HEAT INSULATING LAYER
NOZZLE TIP TEMPERATURE ℃
180
160
140
120
100
0. 00001
0. 0001
0. 001
0. 01
HEAT CONDUCTIVITY λ W/mm/K

FIG. 5

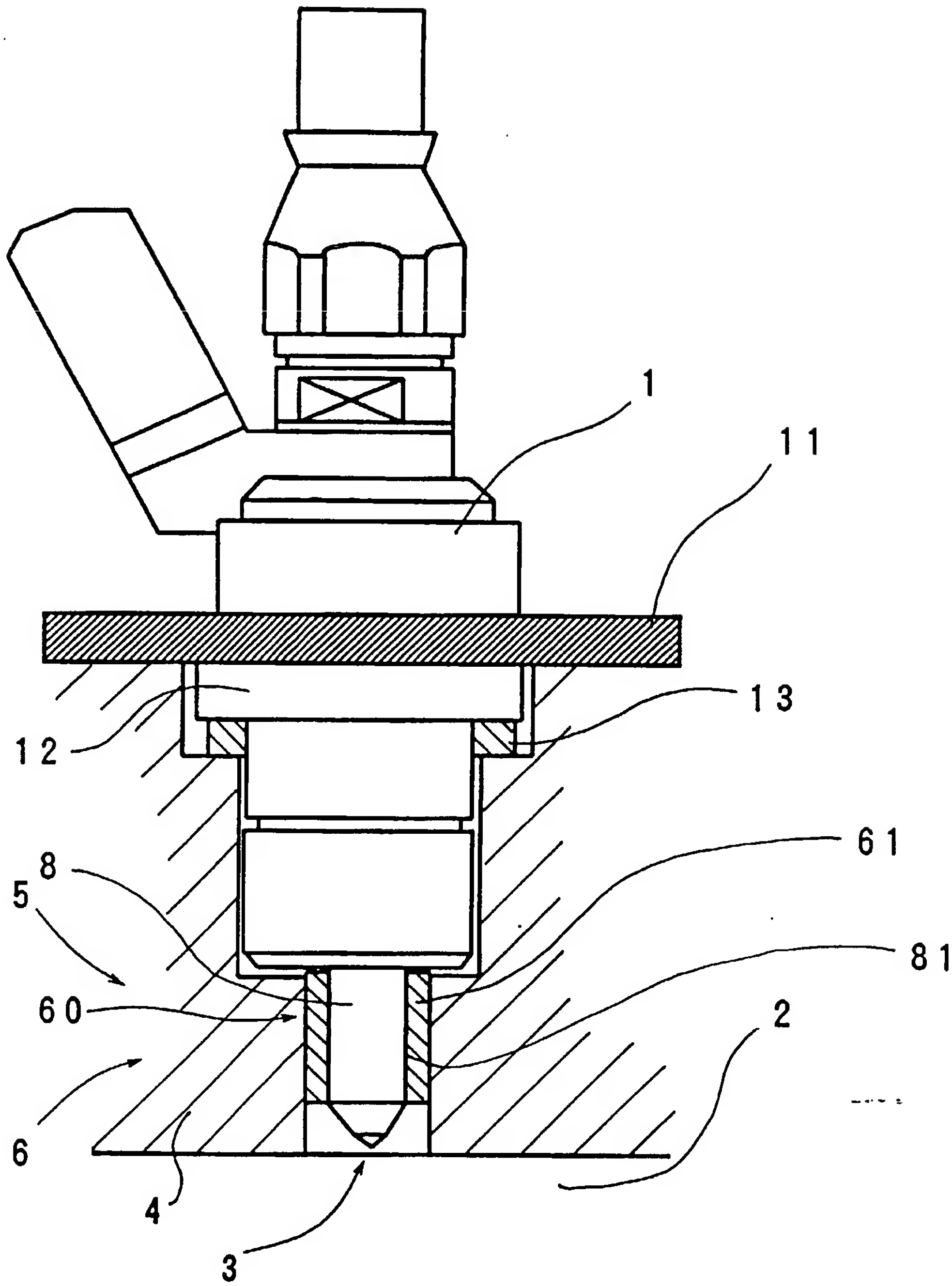


FIG. 6

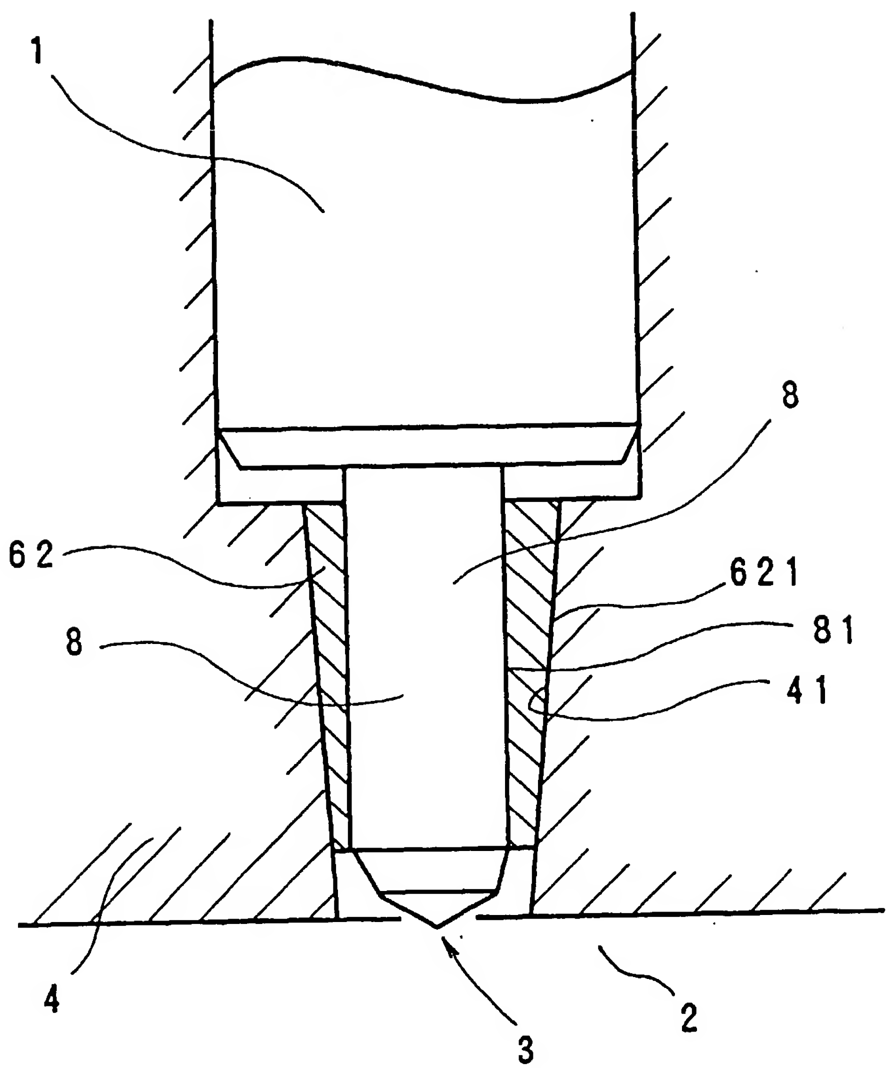
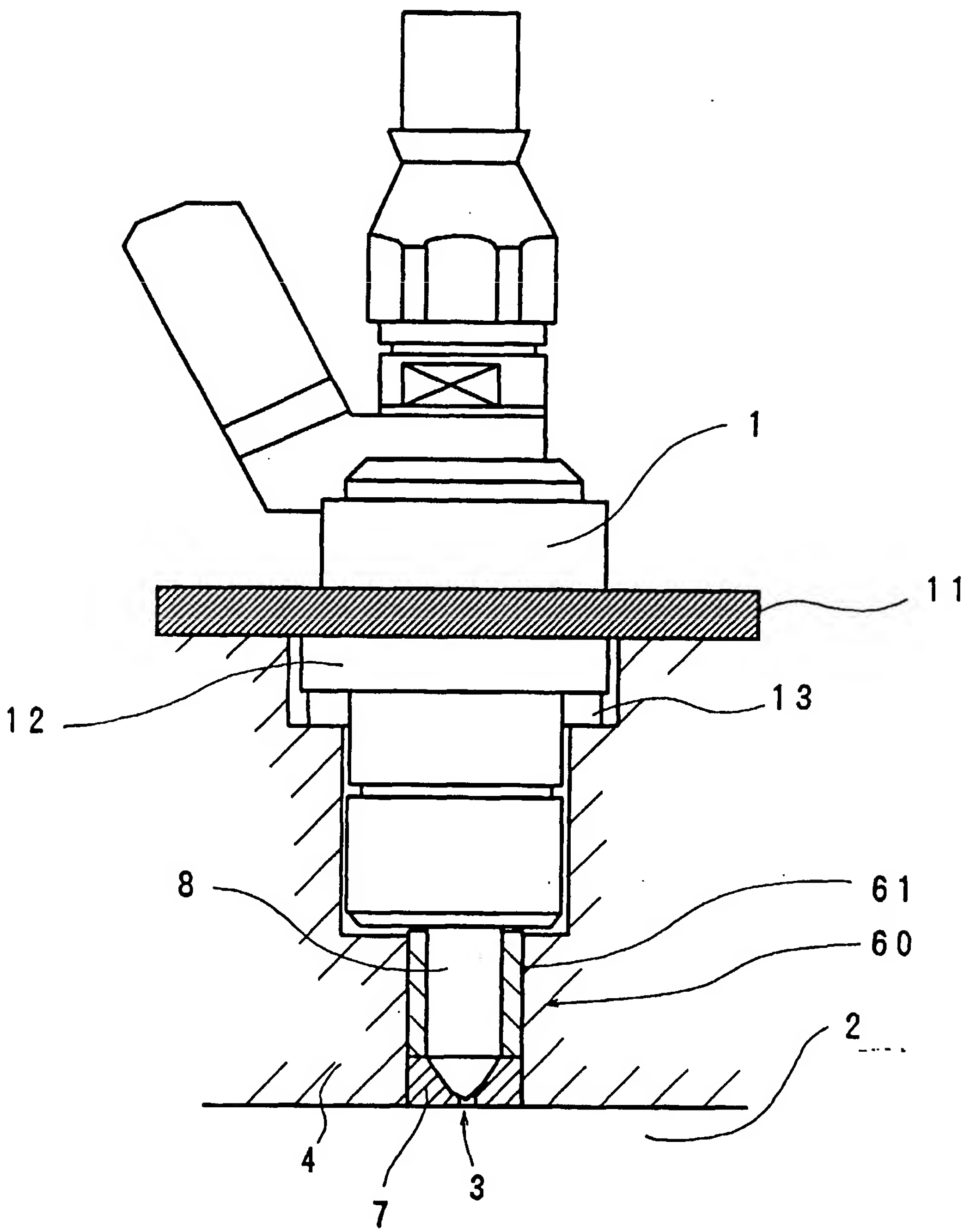


FIG. 7



F I G. 8

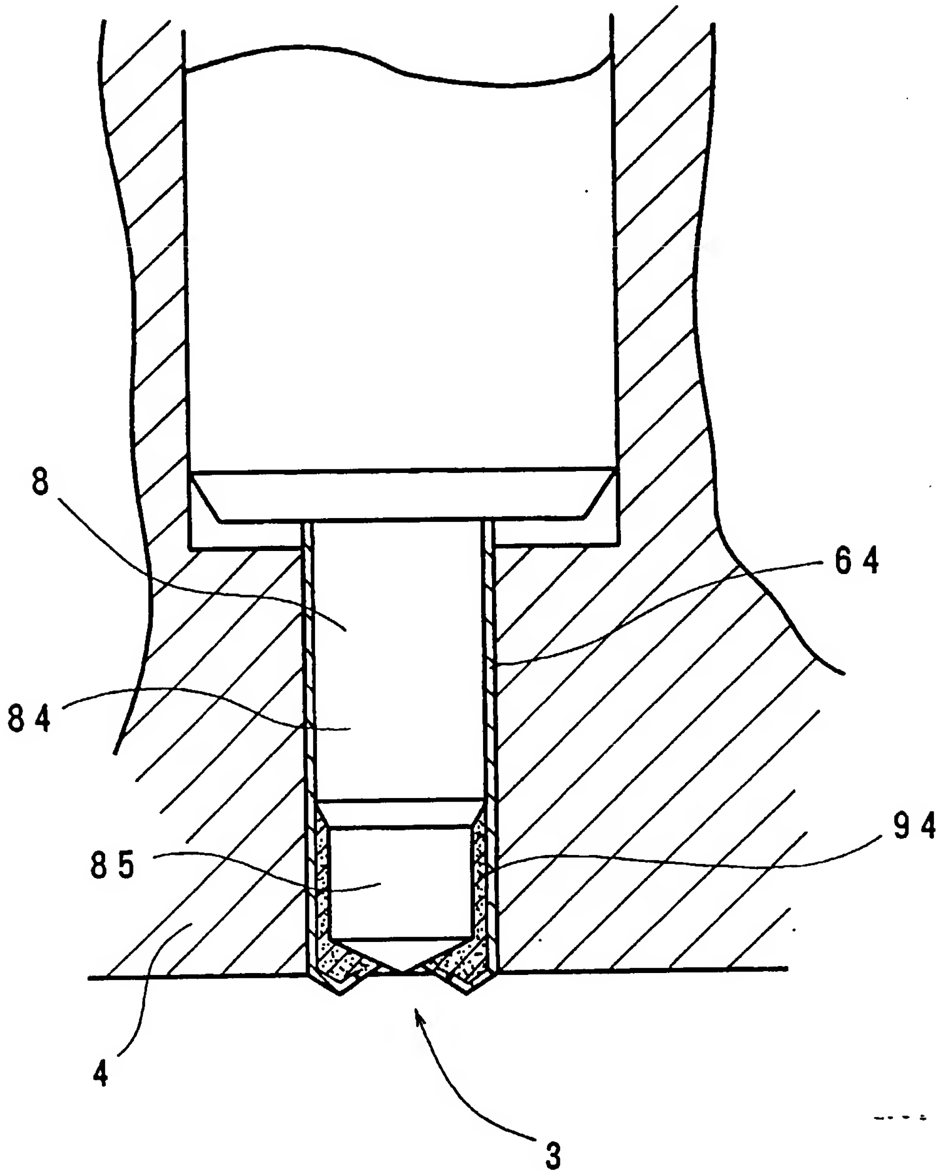


FIG. 9

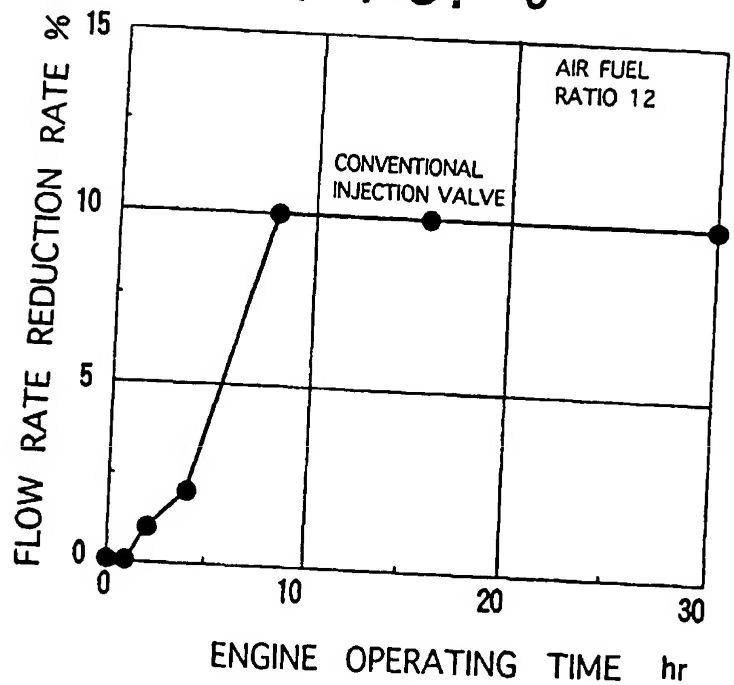

FLOW RATE REDUCTION RATE %
15
10
5
0
0
10
20
30
ENGINE OPERATING TIME hr
AIR FUEL RATIO 12
CONVENTIONAL INJECTION VALVE

FIG. 10

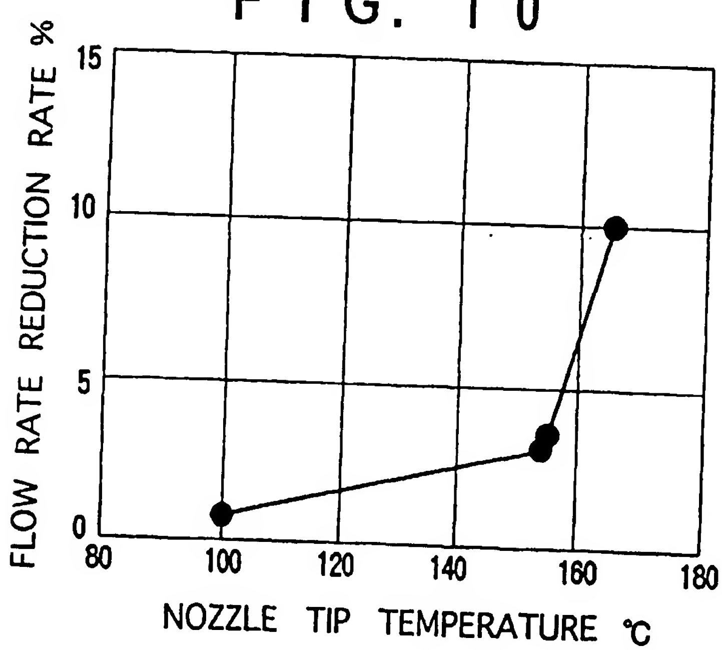

FLOW RATE REDUCTION RATE %
15
10
5
0
80
100
120
140
160
180
NOZZLE TIP TEMPERATURE °C

FIG. 11

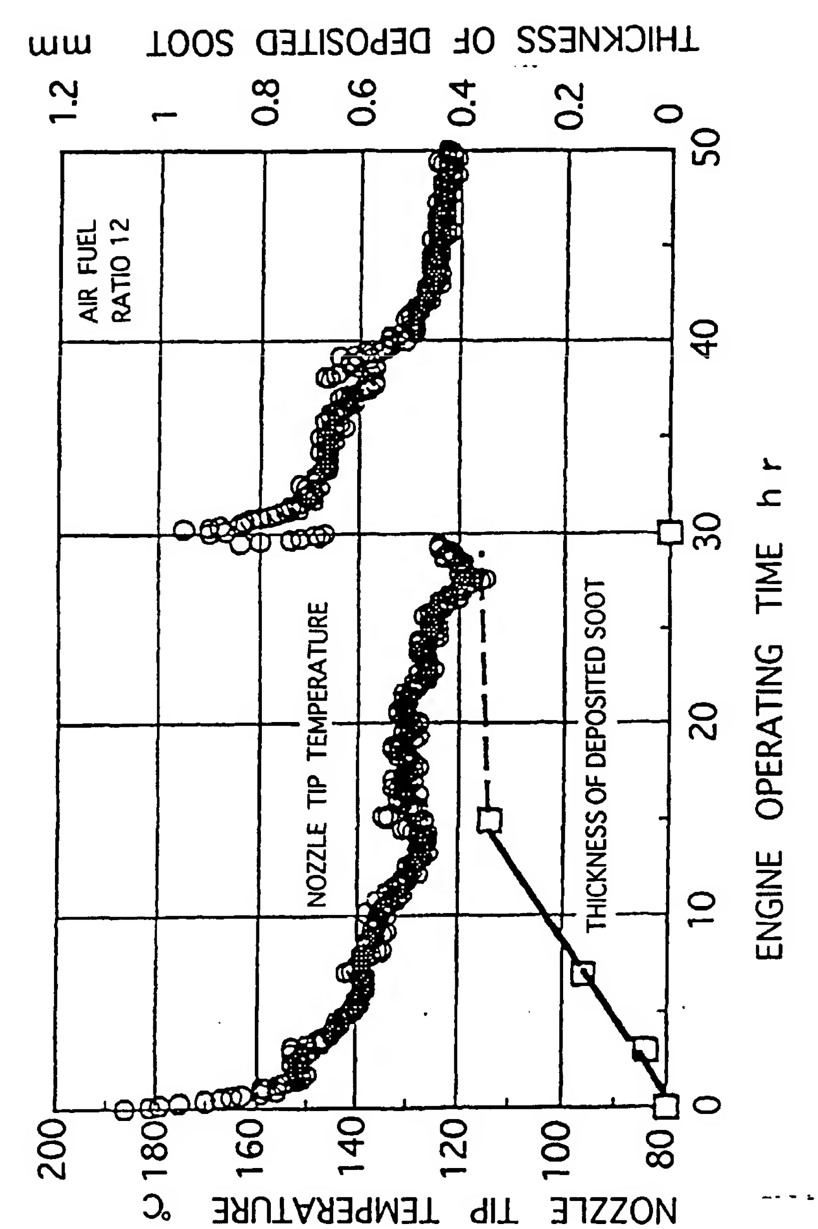

NOZZLE TIP TEMPERATURE ℃
THICKNESS OF DEPOSITED SOOT mm
ENGINE OPERATING TIME hr
NOZZLE TIP TEMPERATURE
THICKNESS OF DEPOSITED SOOT
AIR FUEL
RATIO 12
200
180
160
140
120
100
80
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50

FIG. 12
(PRIOR ART)

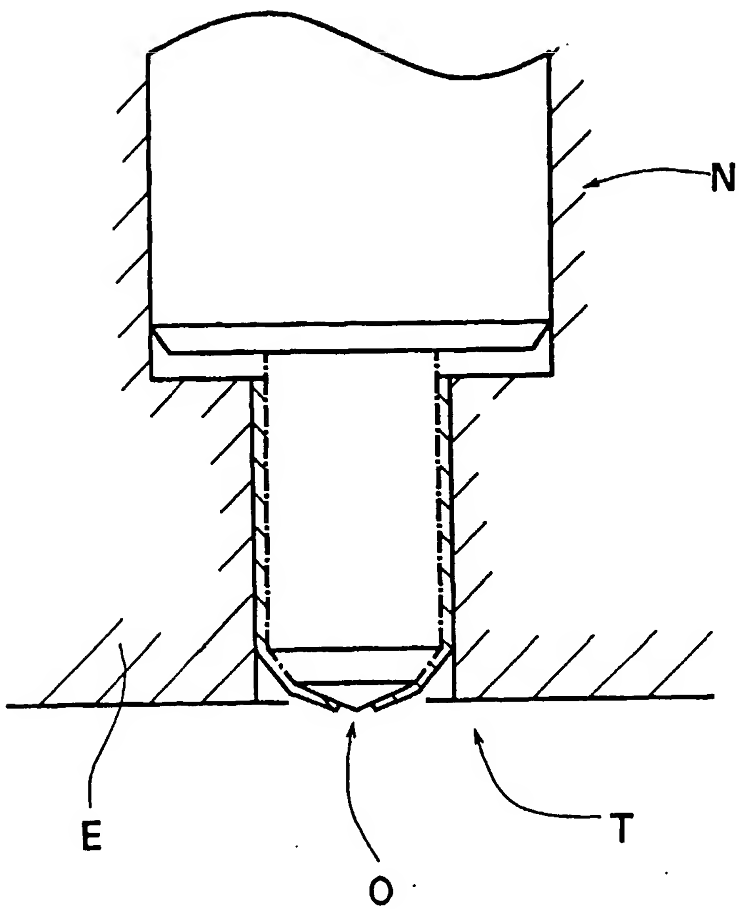


FIG. 13
(PRIOR ART)

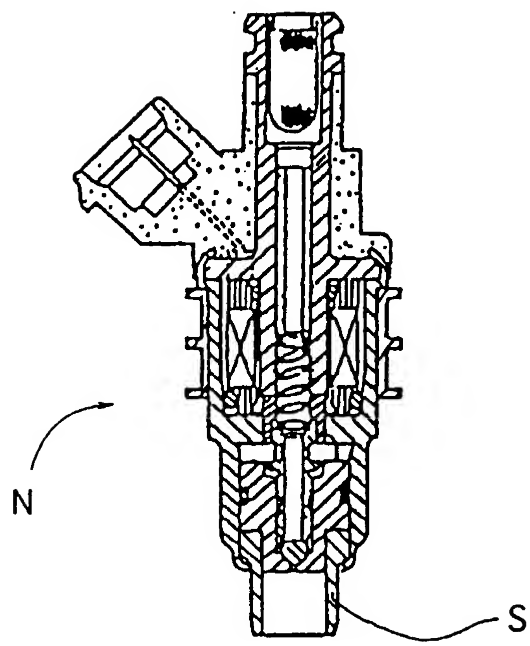


FIG. 14
(PRIOR ART)

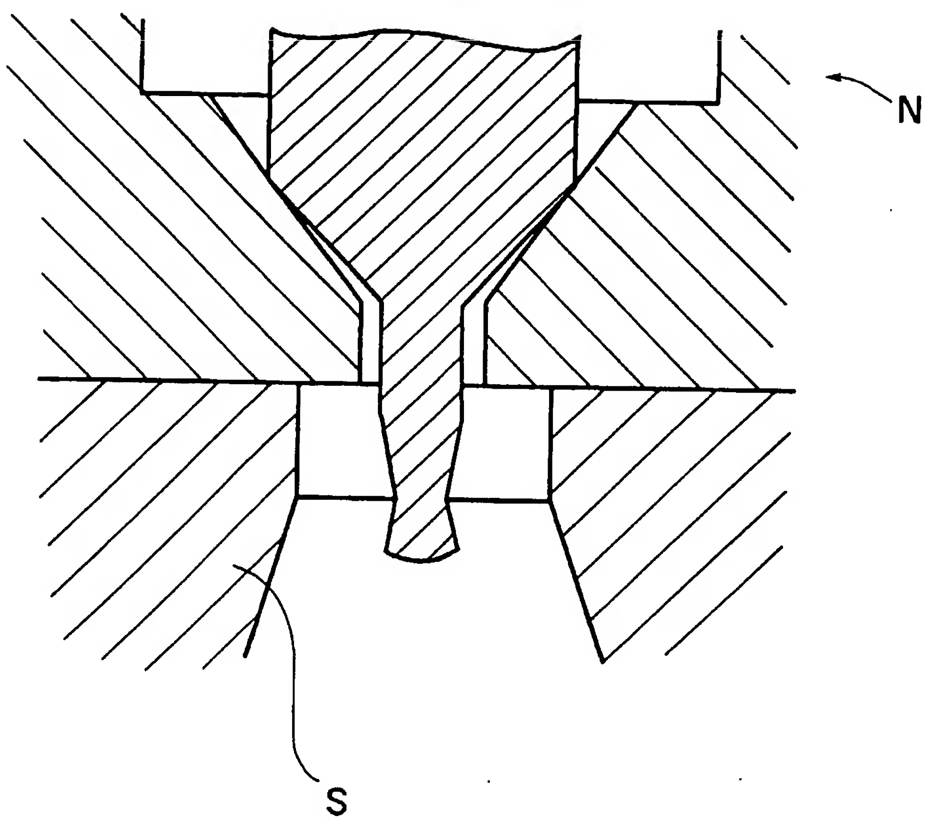


FIG. 15
(PRIOR ART)

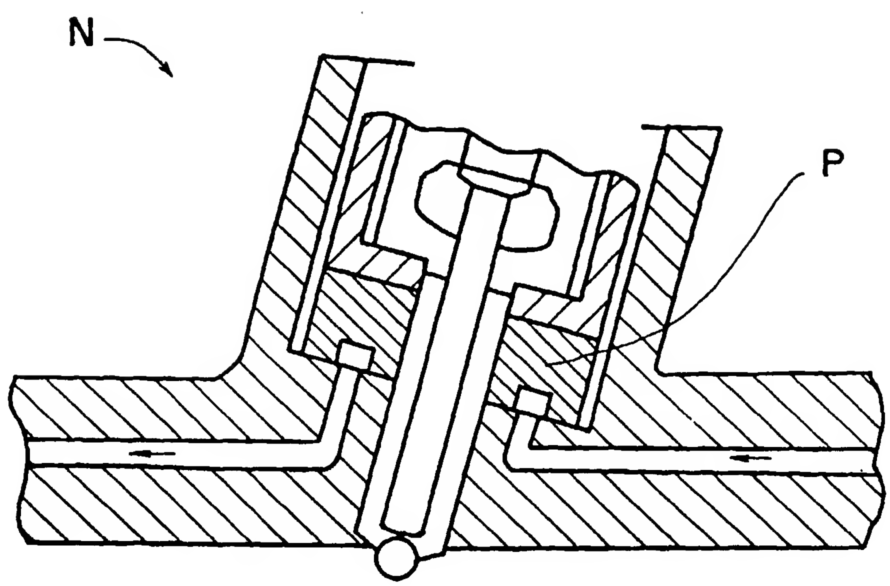


FIG. 16
(PRIOR ART)

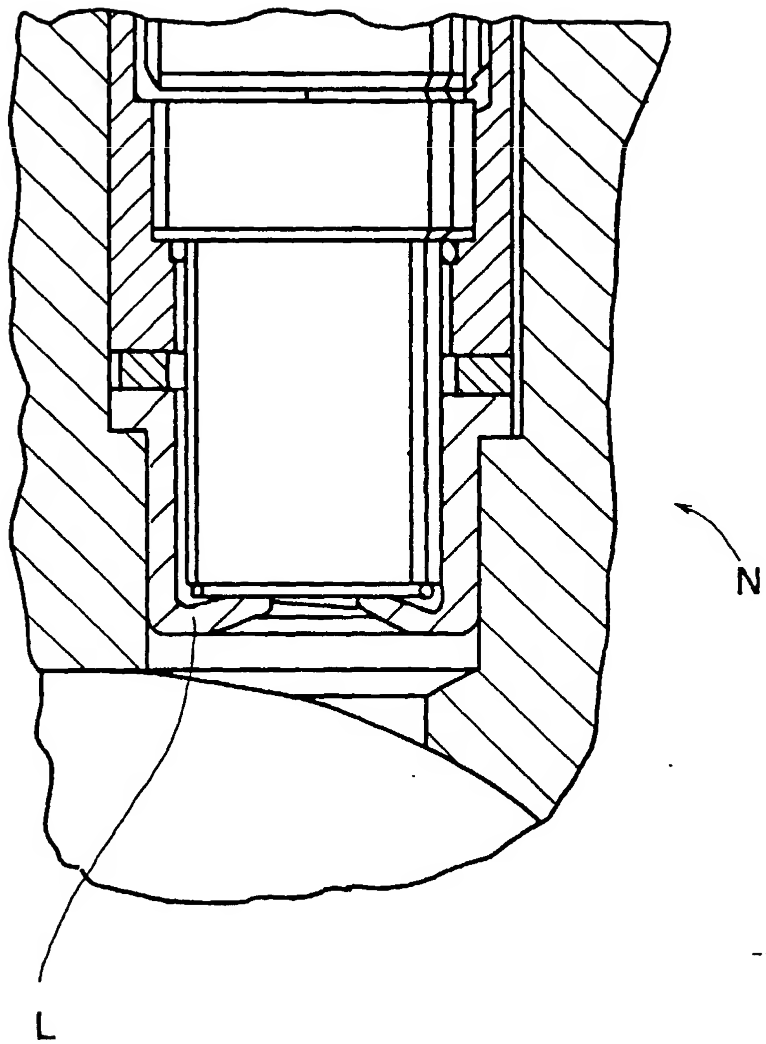
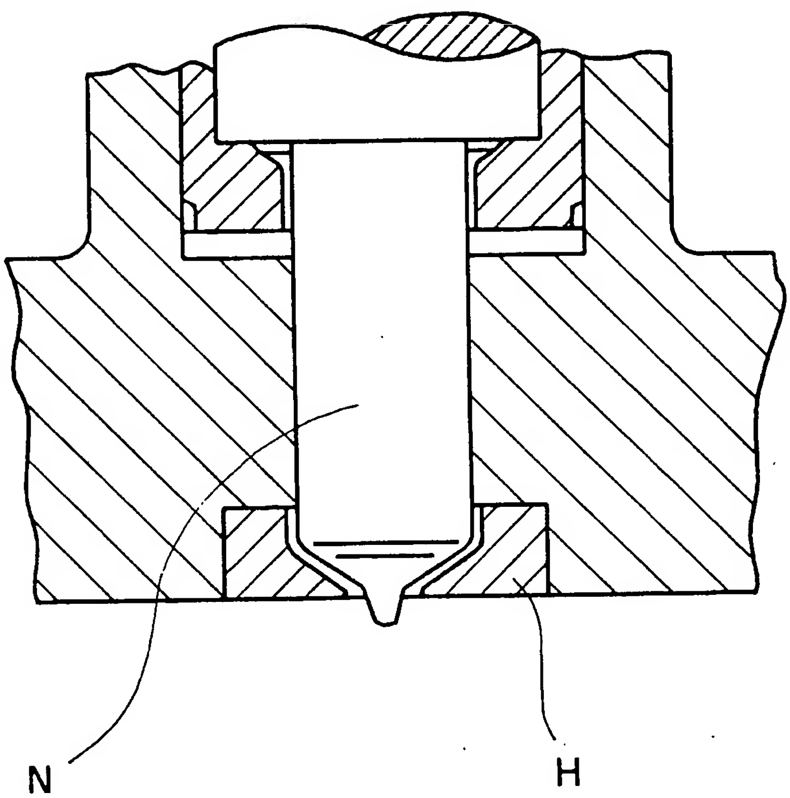


FIG. 17

(PRIOR ART)



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 11 5623

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 2 777 431 A (MEURER) * column 1, line 64 - column 3, line 72; figures *	1-6	F02M61/14
A	GB 719 952 A (ADOLPHE SAURER) * page 2, line 56 - page 3, line 1; figures *	1-3	
A	GB 2 066 895 A (BOSCH GMBH ROBERT) * abstract; figures *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 November 1997	Sideris, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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